9950-1048

DESIGN, FABRICATION AND TESTING OF A MULTIBEAM FORMING NETWORK

FINAL REPORT
JPL CONTRACT 956722
SEPTEMBER 1984

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology sponsored by the National Aeronautics and Space Administration under Contract NAS 7-100

Ford Aerospace & Communications Corporation
Western Development Laboratories Division

3939 Fabian Way
Palo Alto, California 94303

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WESTERN DEVELOPMENT LABORATORY

FORD AEROSPACE AND COMMUNICATIONS COMPANY

3939 FABIAN WAY, PALO ALTO, CALIFORNIA 94303

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ABSTRACT

A JPL concept for a multiple beam forming network to route signals from eight input ports to twenty-one output ports so as to form eight independent seven-element cluster radiators has been designed, fabricated, and tested. The operating frequency band is 2.226 to 2.254 GHz and the maximum power to any input port is two watts.

The network consists of eight seven-way power dividers connected to twenty-one seven-way power combiners. The network utilizes barline circuits between parallel ground planes for the power distribution and collection. Interconnections are made with short rigid co-axial lines built into the network.

The concept, general design procedures, mechanical configuration, and electrical performance are described in this report. It appears that the network is quite satisfactory for demonstrating practical feasibility of the technical concept.

INTRODUCTION

The purpose of this multiple beam forming network is to route signals from eight input ports to twenty-one output ports so that each separate signal excites a feed cluster of seven elements. The concept for accomplishing this and the performance specifications were developed at JPL and are described in detail in the Statement-of-Work part of the contract. The specifications are summarized in the Requirements Section that follows.

The objectives of this development program have been to:

1. Design barline power dividers and power combiners to distribute the signals within the required electrical tolerances.

2. Design a mechanical configuration that provides the desired networks' interconnections.

3. Fabricate the network, measure its performance and deliver it and a final report to Jet Propulsion Laboratory.

The network consists of eight seven-way power dividers connected to twenty-one seven-way power combiners providing equal electrical path lengths between input and output ports. Barline circuits between parallel ground planes are used throughout with the power dividers in one plane and the power combiners in an adjoining parallel plane. Interconnections are made by short coaxial lines built into the structure.

Ground planes are made of honeycomb-spaced aluminum sheets to provide mechanical stiffness. The complete system consists of five layers, three honeycomb sheets and two barline circuit planes. Input-output is accomplished with SMA connectors.

This program has been completed and tests indicate the equipment is suitable for demonstrating practical feasibility of the technical approach.

REQUIREMENTS

The physical configuration and circuit diagrams for the network are shown in Figures 1 and 2, taken from the contract. The network is planar with all of the 8 beam ports on one side of a center ground-plane and all of the 21 antenna ports on the other side.

Provisions are made for the interchange of fixed attenuators (values of 0, 1, 2, 3, 5 dB) in each of the 8 input networks to vary the excitation of the cluster center element. With the 0 dB attenuator installed the nominal difference between the cluster center element excitation and each peripheral element excitation is 15 dB.

The specified performance characteristics are:

Operating frequency - 2.226 to 2.254 GHz

Insertion loss - less than 1.5 dB

Isolation - 20 dB for connected ports
40 dB for unconnected ports

Amplitude balance - less than 0.3 dB deviation from nominal

Phase balance - less than 5 electrical degrees spread

VSWR - less than 1.2

Power handling capacity - 2 watts maximum

Size - less than 60 x 60 x 2.0 inches

Weight - less than 20 pounds

RF connectors - SMA jack type

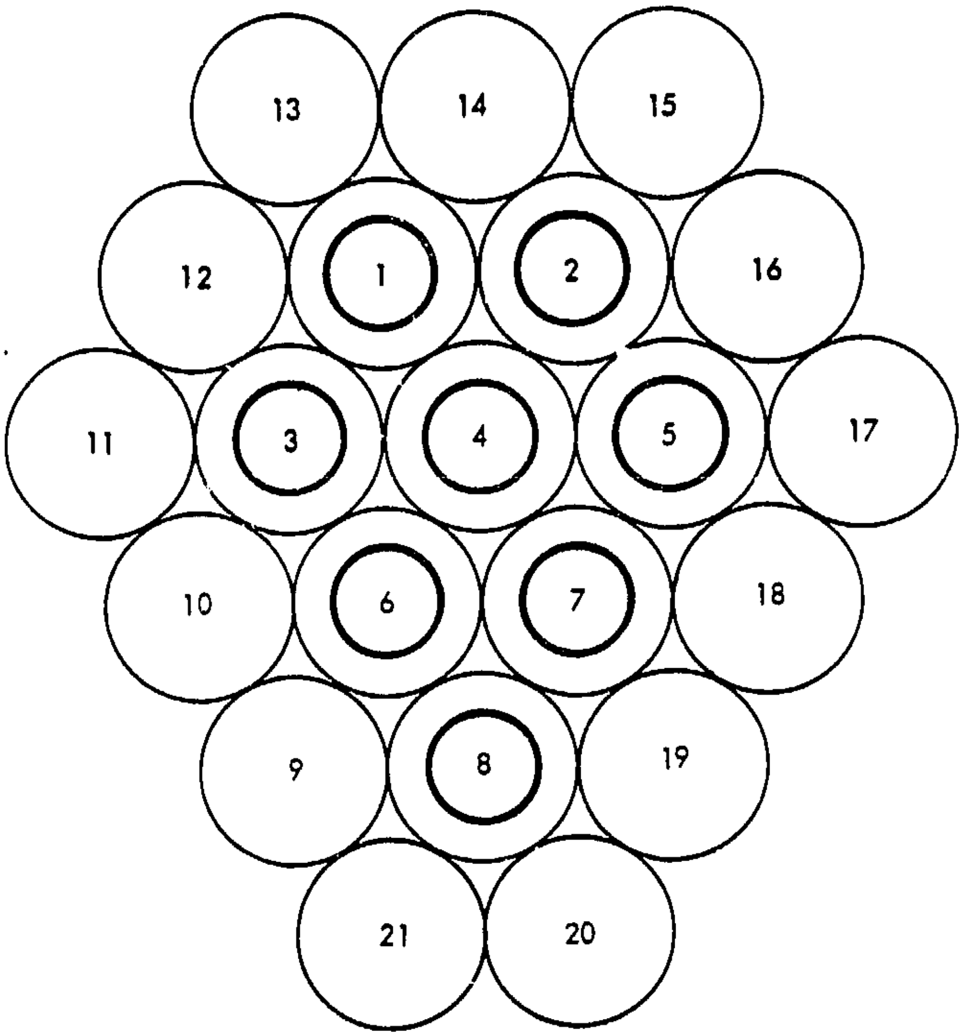


FIGURE 1 OUTLINE OF 21 FEED ELEMENTS (LIGHT CIRCLES) AND 8 BEAMS (DARK INNER CIRCLES). EACH BEAM IS PRODUCED BY A CENTER ELEMENT AND SIX SURROUNDING ELEMENTS.

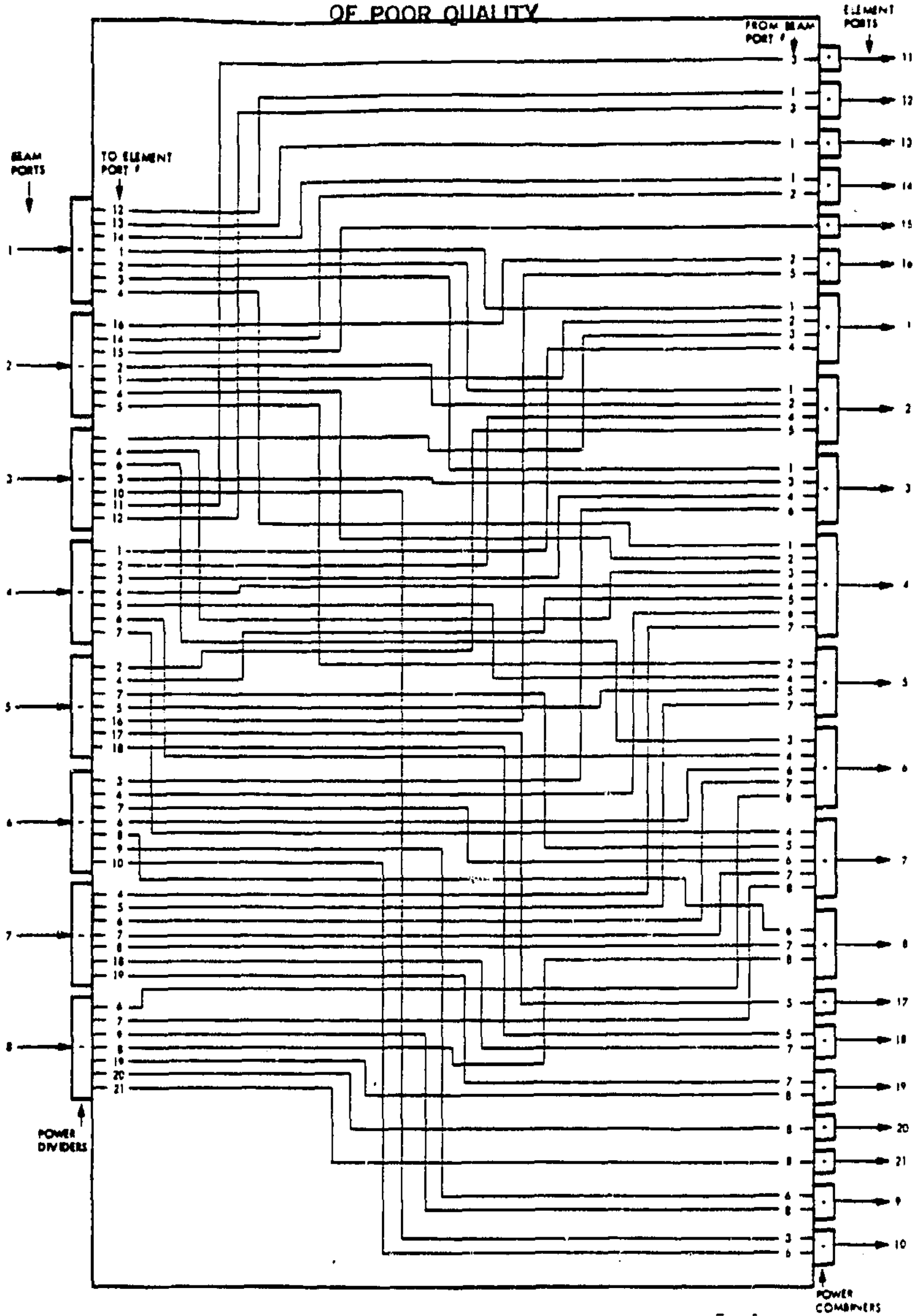


FIGURE 2 MULTIBEAM FORMING NETWORK SCHEMATIC FOR OVERLAPPING 7-ELEMENT CLUSTER CONFIGURATION

NETWORK ELECTRICAL CIRCUIT

The electrical circuit of Figure 2 was implemented using eight power dividers and twenty-one power combiners interconnected as shown in Figure 3.

In order to meet the isolation requirements, Wilkinson isolated power dividers were used as the basic network element to build the complete 1 to 7 module. Although a slight power loss is incurred, a choice was made to use a 1 to 8 divider network with two dummy terminations rather than a 1 to 6 network to excite the peripheral elements. This resulted in a reduced design effort as well as providing greater assurance of matched line lengths throughout. The Wilkinson power dividers and basic network are shown schematically in Figures 4 to 6 where it may be seen that one uneven (2.31 dB - 3.84 dB) Wilkinson divider and seven even (3.01 dB - 3.01 dB) Wilkinson dividers are used. Power to the two unused terminals is terminated in 50 ohm pill-type resistors. About 15% of the input power is lost in these two dummy terminations. (The same proportional loss occurs in the combiners giving a total loss of 30% or an equivalent insertion loss of about 1.37 dB).

External connections are made to these circuits by means of coaxial dams. A dam consists of an SMA co-axial connector and a U-shaped shorting bar built together as illustrated in Figure 14. The U-shaped shorting bar provides both an electrical and mechanical connection to the ground plane.

The design procedure was to first fabricate, test and modify models of the even and uneven Wilkinson dividers. Then complete dividers and combiners were fabricated and tested. The tests included measurements of VSWR and transmission between port terminals.

Typical measured data for the final individual Wilkinson dividers are shown in Figure 7. These data show that the design should be satisfactory for the present application; although the relative attenuation of one side of the uneven divider is 0.1 dB high.

A center line drawing for the combiner network is shown in Figure 8 and a reproduction of the combiner photomask is shown in Figure 9. Both of these figures show the co-axial dams in place. Measured data for the prototype combiners, displayed in Figure 10, shows about 0.3 dB deviation from specification for the relative attenuation of an edge element compared to the center element.

The power dividers are identical to the power combiners except for the relocation of the major output line to provide for the addition of external attenuators to adjust the relative excitation center element. This difference may be clearly seen by comparison of the pictures in Figures 19 and 20.

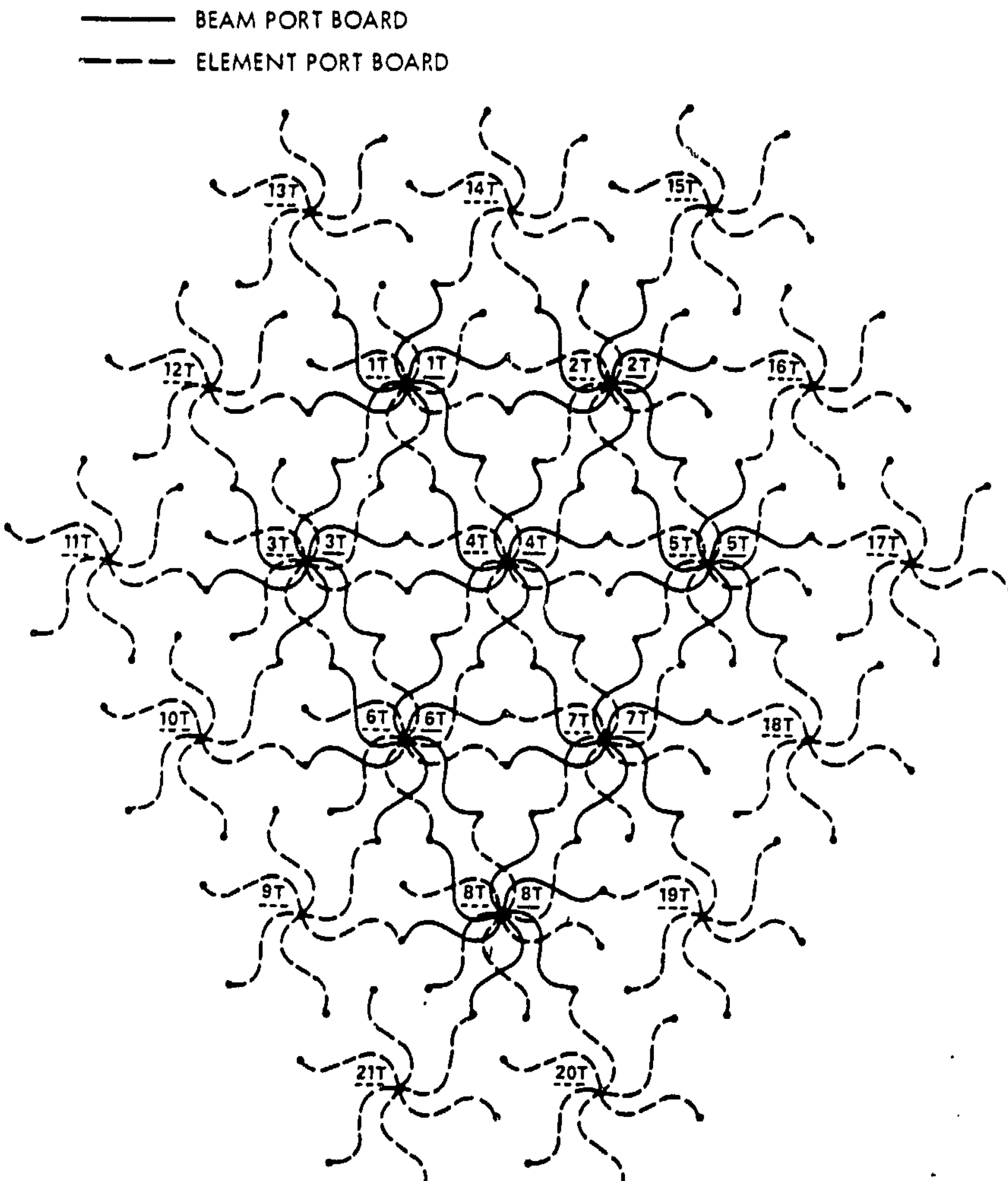


FIGURE 3 TOP VIEW OF BEAM PORTS BOARD (BPB) AND ELEMENT PORTS BOARD (EPB) INTERCONNECTION

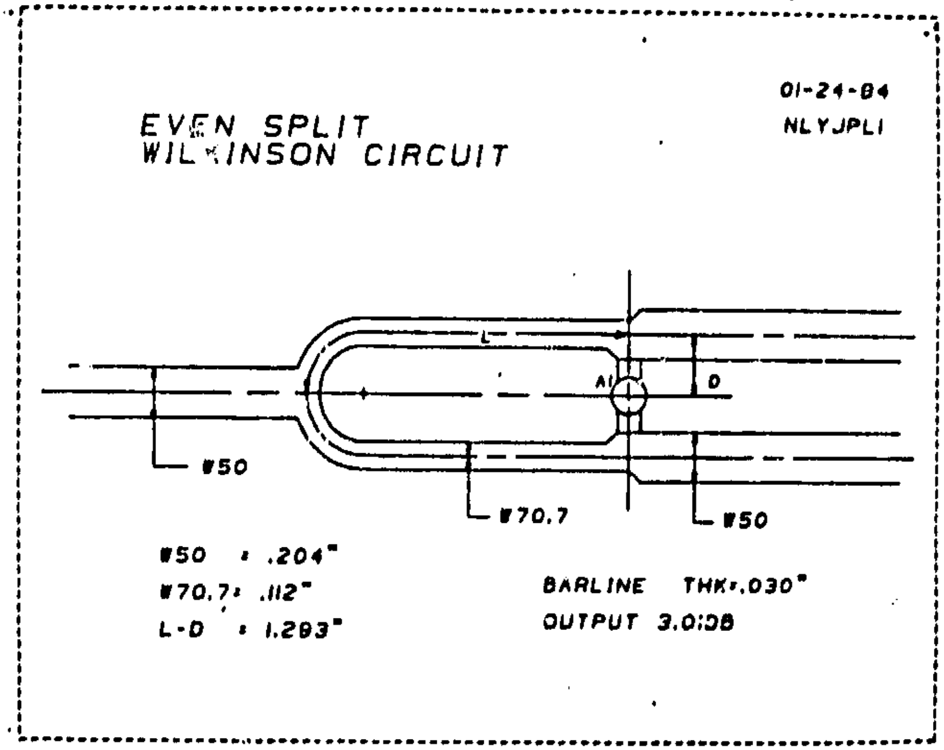


FIGURE 4 WILKINSON DIVIDER CIRCUIT,
EVEN SPLIT 3.01-3.01 dB

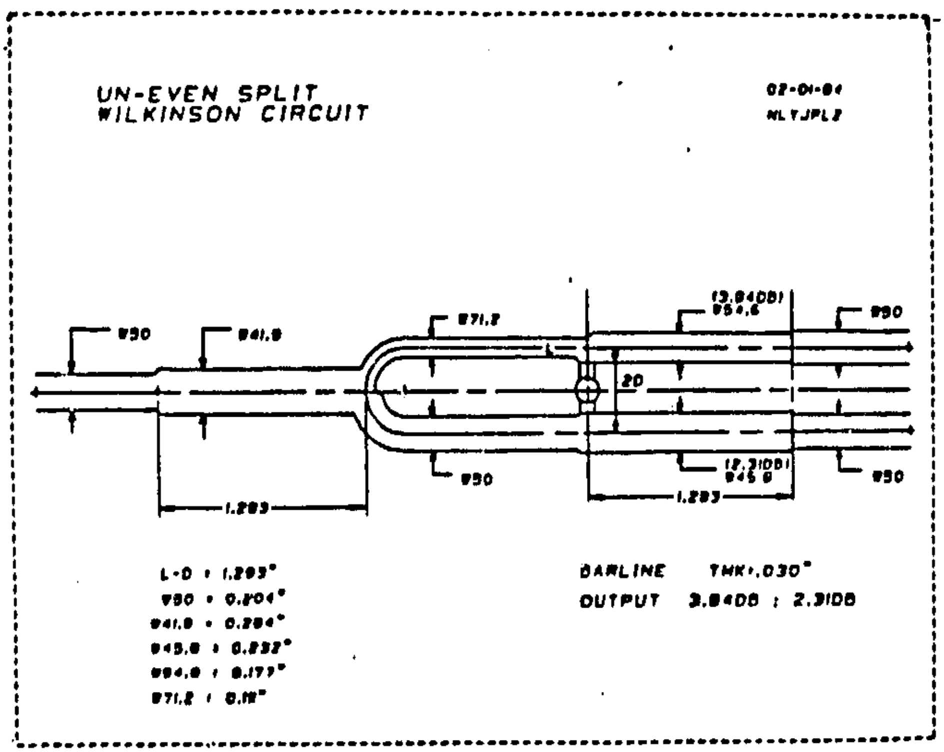


FIGURE 5 WILKINSON DIVIDER CIRCUIT,
UNEVEN SPLIT 3.84-2.31 dB

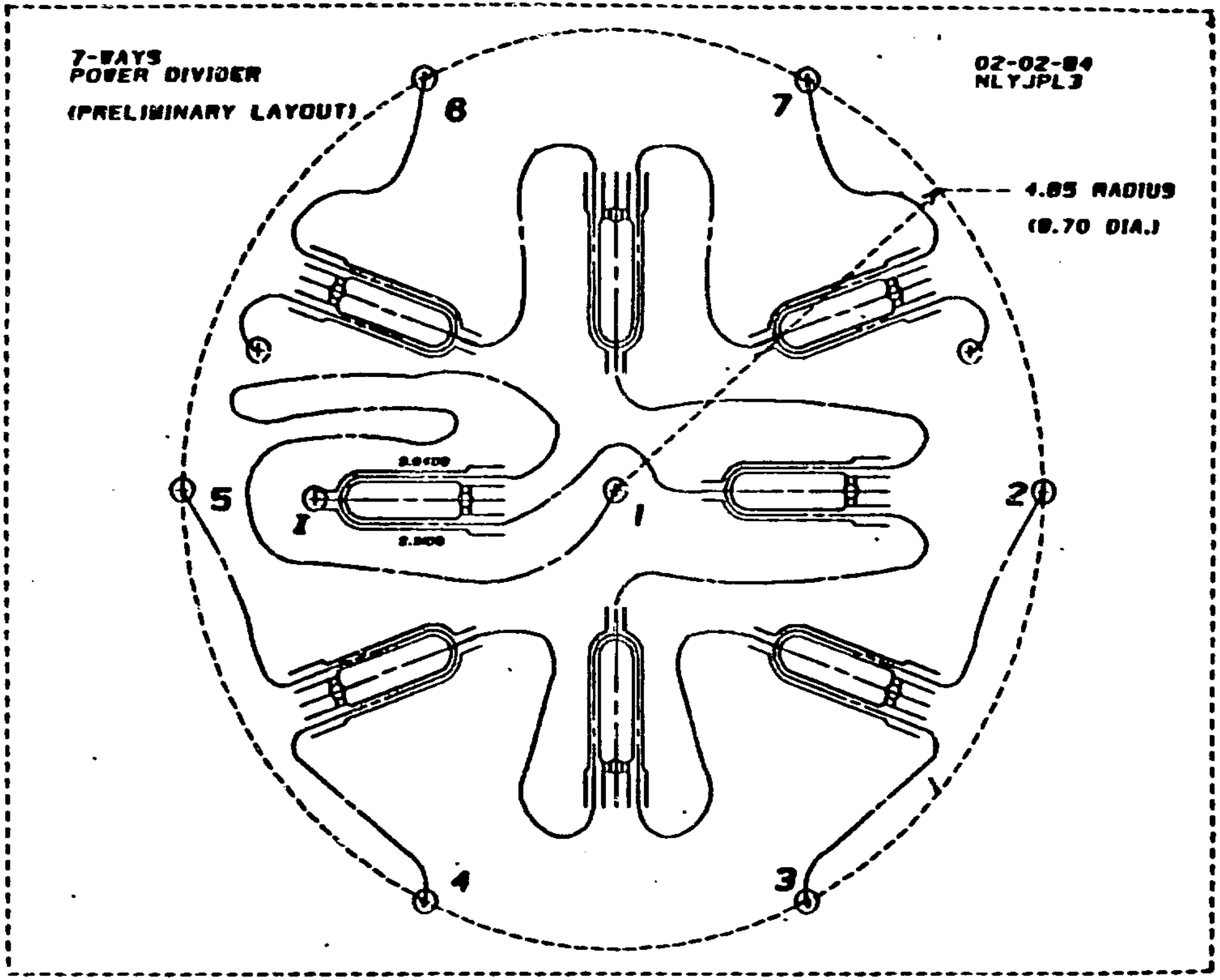
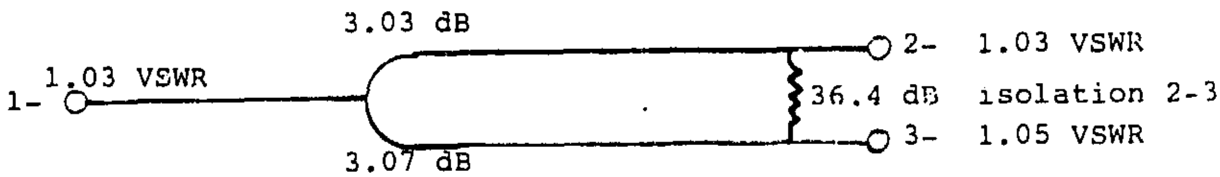


FIGURE 6 POWER DIVIDER NETWORK MODULE



EVEN SPLIT WILKINSON DIVIDER MEASURED PARAMETERS
(The Attenuation Goal was: 1-2, 1-3, 3.01 dB)

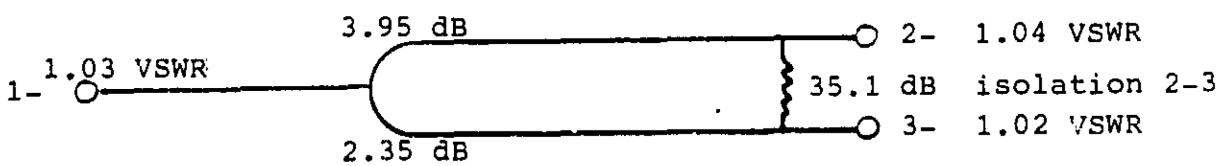


FIGURE 7 TYPICAL MEASURED DATA FOR FINAL DESIGN WILKINSON DIVIDERS

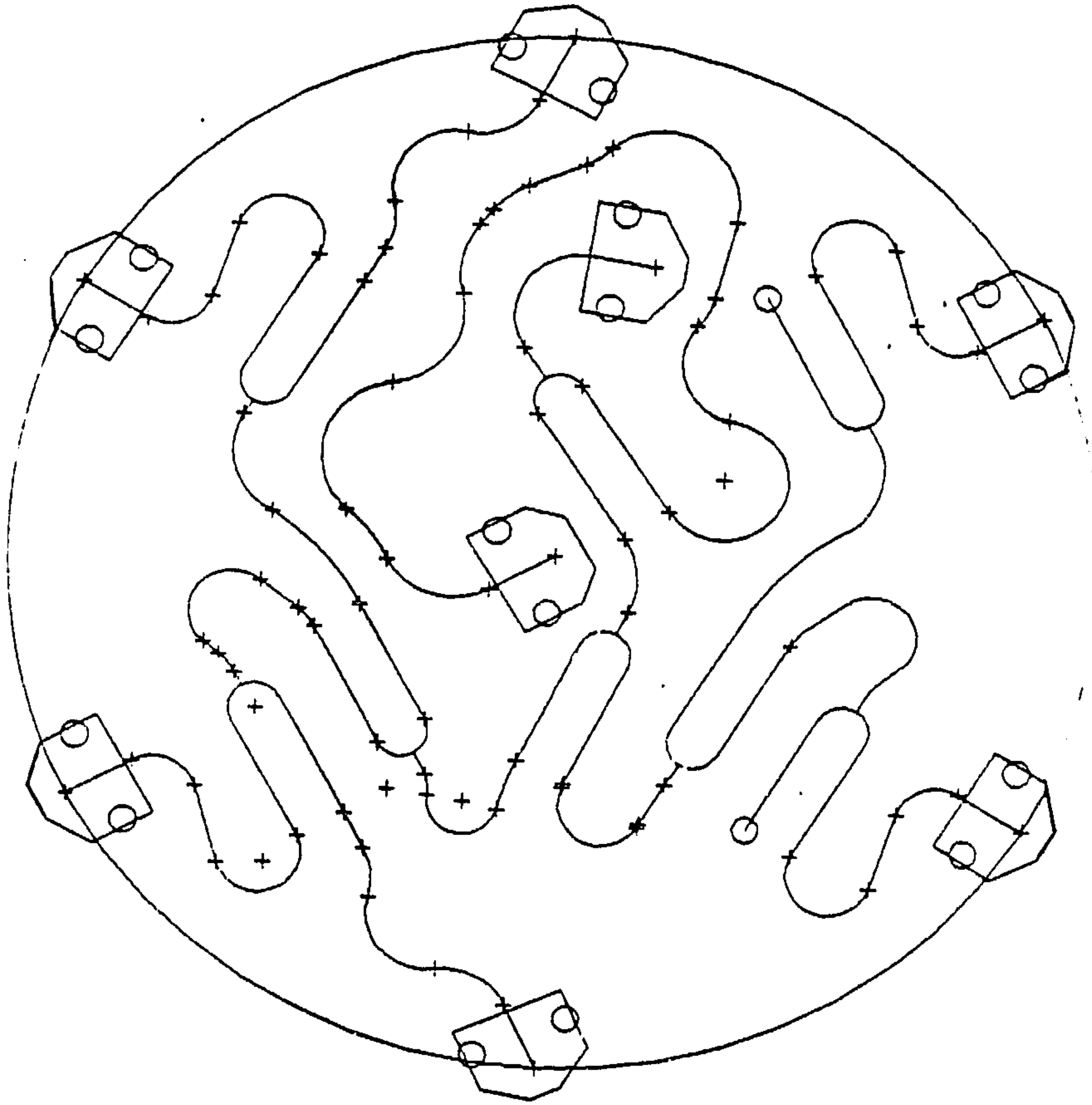


FIGURE 8 COMBINER NETWORK, CENTER-LINE DRAWING

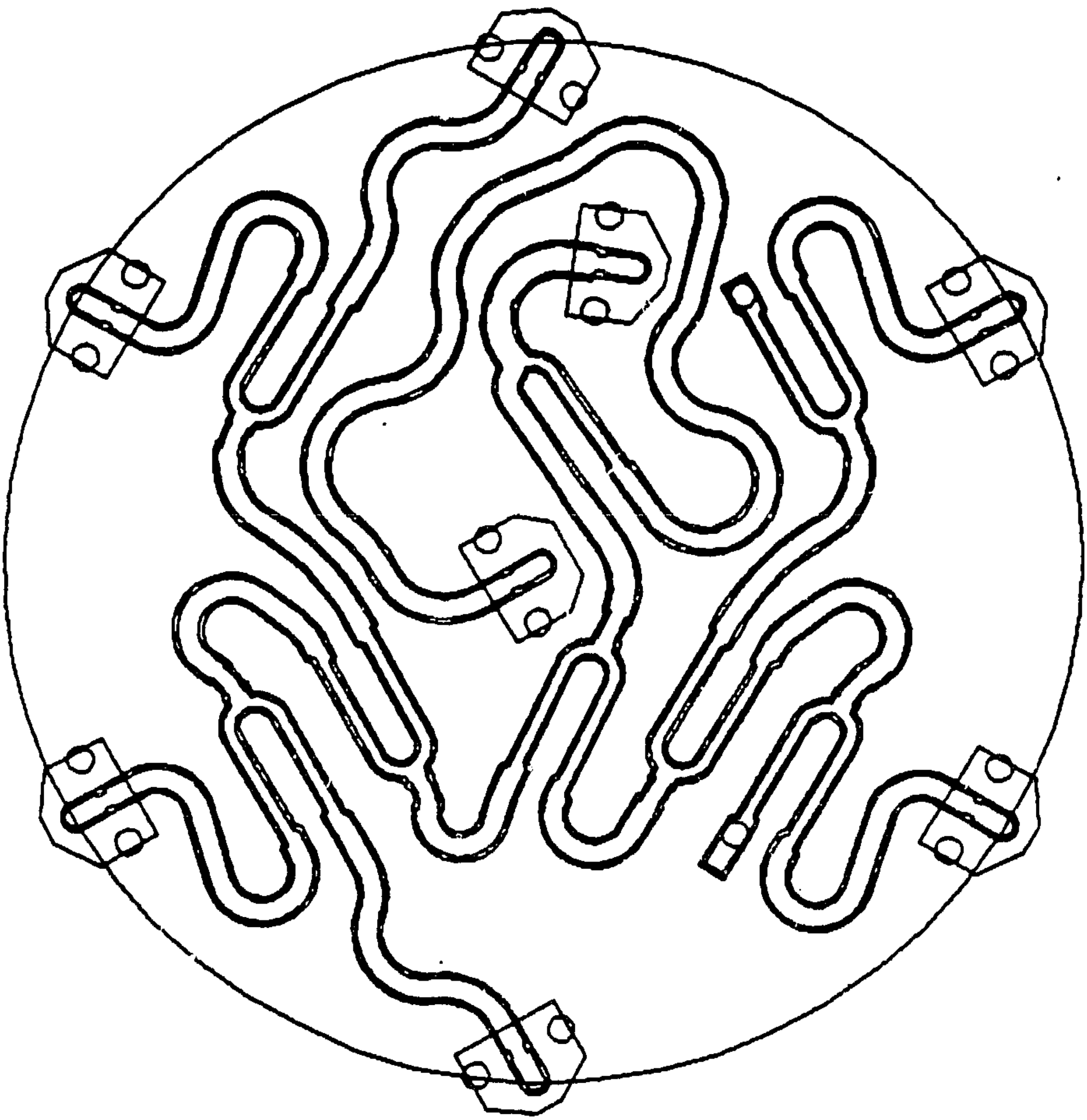


FIGURE 9 COMBINER NETWORK PHOTOMASK DRAWING

PORT	ANTENNA	CENTER	PERIPHERAL					
			1.	2	3	4	5	6
VSWR (TEST)	1.10	1.15	1.03	1.07	1.09	1.08	1.08	1.10
SPECIFICATION	1.2							
MEASURED LOSS (DB)		4.24	11.4	11.4	11.4	11.3	11.4	11.4
SPECIFICATION		3.84	11.34					
MEASURED PHASE (DEGREES)		-4.4	2.8	1.6	0.1	2.5	2.4	1.6
SPECIFICATION		5 DEGREE SPREAD						

FIGURE 10 COMBINER (7-1) TEST RESULTS

MECHANICAL CONFIGURATION

The mechanical arrangement provides the interconnections between a planar set of eight power dividers and a planar set of twenty-one power combiners as required by Figure 3. It turns out that the peripheral interconnect points of the two sets of networks align precisely when the two sets are oriented as shown in Figures 11 and 12. The relative angular positions of the dividers and combiners is 40 degrees.

Figure 13 shows the relationships between the divider and combiner dams. One of the mechanical problems was to orient the U-shaped dams so that the screw locations for the combiners did not interfere with the screw locations for the dividers.

A cross-section of the assembled network showing the two planar constituent barline circuits is given in Figure 14. This drawing shows the attachments of the interconnecting coaxial lines. The connectors' dimensions are standard SMA and the internal coaxial dimensions are chosen to provide a 50 ohm impedance. The 50 ohm barline is attached to the coaxial center conductor with a small screw. Although it is not shown clearly in this figure, the dam structure wraps around this coax to barline joint. The dams act as mechanical spacers and also provides a low impedance electrical connection between the ground planes. The complete structure is held together by screws that press the honeycomb layers against the dams.

Interconnections between the two planar circuits utilizes similar dams that fit together using split tube fingers for electrical contact.

The drawing of Figure 15 shows the locations of input and output ports as well as the positions of the mounting inserts. (Note that the port numbering scheme in Figure 15 is different from that of Figure 1. The numbers on the actual equipment correspond to Figure 1.)

The overall mechanical configuration can best be seen in the three photographs of Figures 16 to 18. Photographs of the combiner and divider networks are shown in Figures 19 and 20.

The weight of the completed network is 25.45 pounds, a value that can be reduced by using sheet adhesive rather than rolled-on adhesive as was used in fabricating the honeycomb sheets for this unit.

Steps that led to this final model were:

A. Dividers and Combiners

1. Mechanical drawing for individual Wilkinson dividers (even and uneven types) were made on the CAD units, resulting in masks suitable for photo-etching.

2. After electrical testing the drawings were modified and incorporated into complete combiners and dividers as shown by the center-line drawing of Figure 8. The CAD unit then produced a photomask drawing similar to Figure 9. These masks were then used to photoetch the circuits shown in Figures 19 and 20.

3. Resistors and terminations were added to these dividers and combiners as shown in Figure 20. Then the networks were mounted between parallel plates with dams added as shown in Figure 19.

4. After testing and modification, the network designs were finalized.

B. Dam Development

Dams were designed and samples fabricated and tested by utilizing a sliding load on a straight section of barline. These measurements led to specification of a matching modification for the network barlines.

C. Ground Plane Design

Because of weight limitations and stiffness requirements, it was necessary to use custom made honeycomb materials rather than standard commercial material. A cross-section of the assembled network showing the two planar constituent barline networks is given in Figure 14 and an interconnection diagram is shown in Figure 15. The completed structure is held together by screws that press the honeycomb layers against the dams.

The overall configuration can best be seen by examination of the three photographs of Figures 16 to 18. Photographs of the combiner and divider networks are shown in Figures 19 and 20.

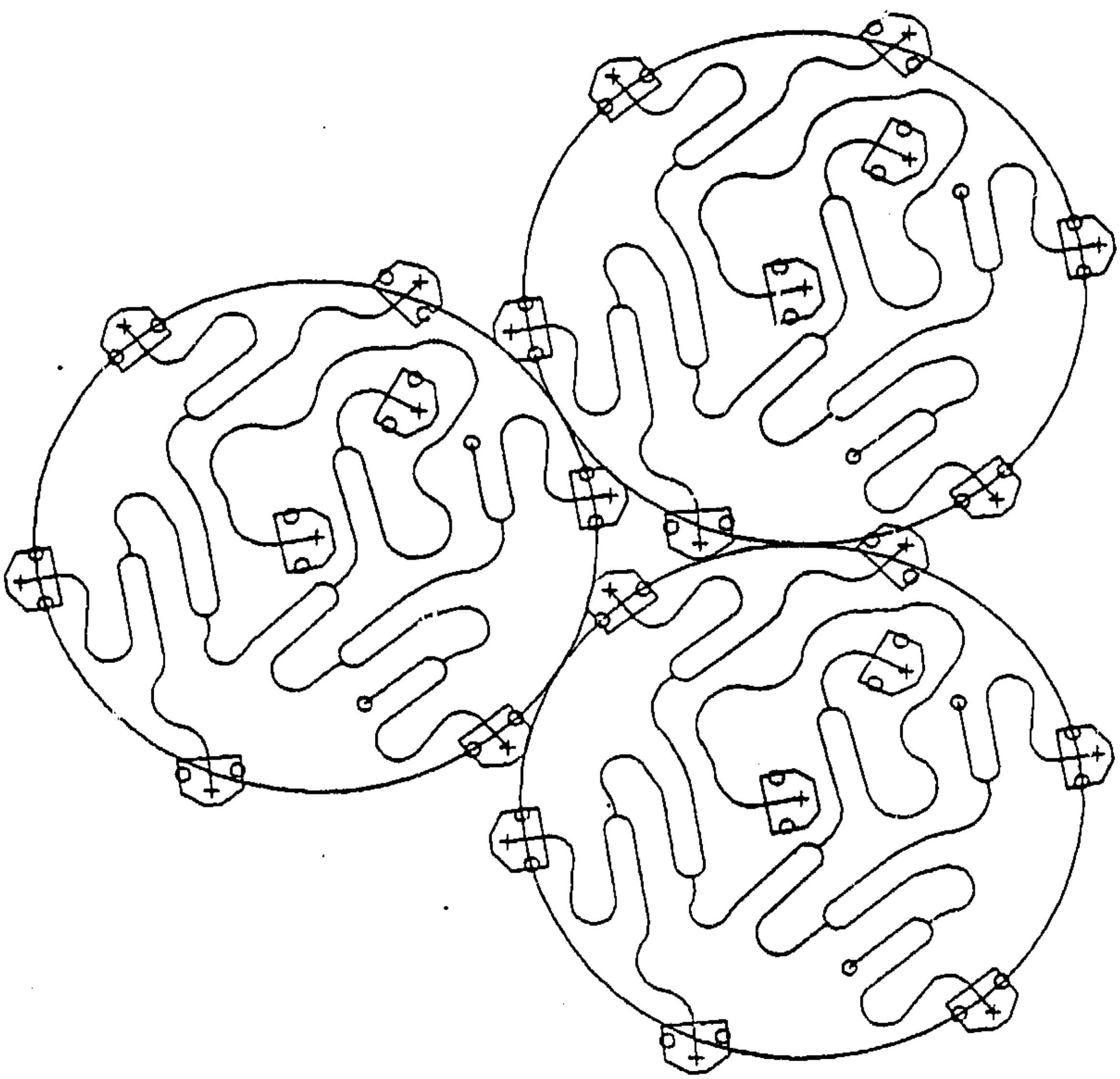


FIGURE 11 BEAM PORT SYSTEM LAYOUT CW 20° ROTATION

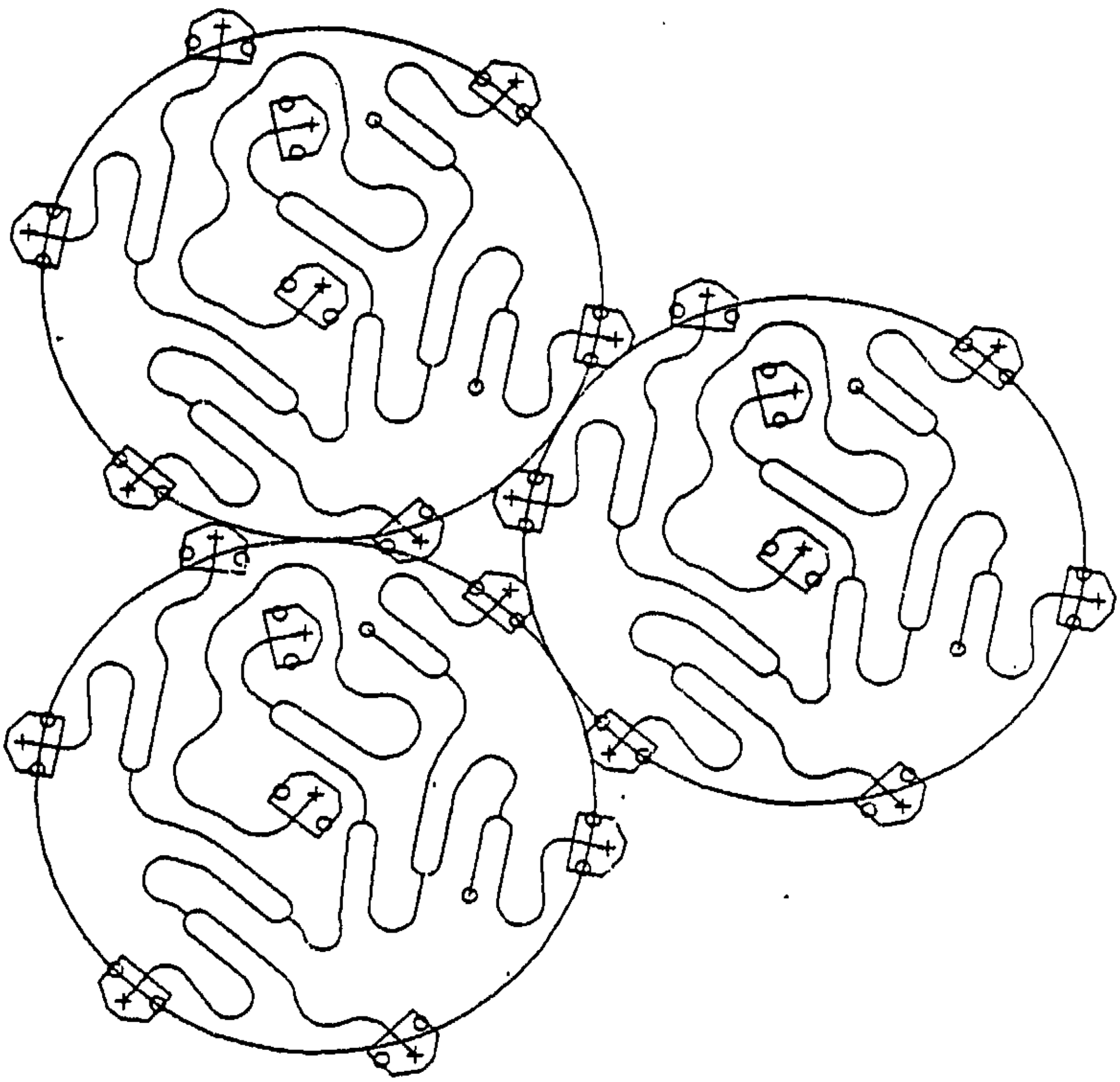


FIGURE 12 ANTENNA PORT SYSTEM LAYOUT CCW 20° ROTATION

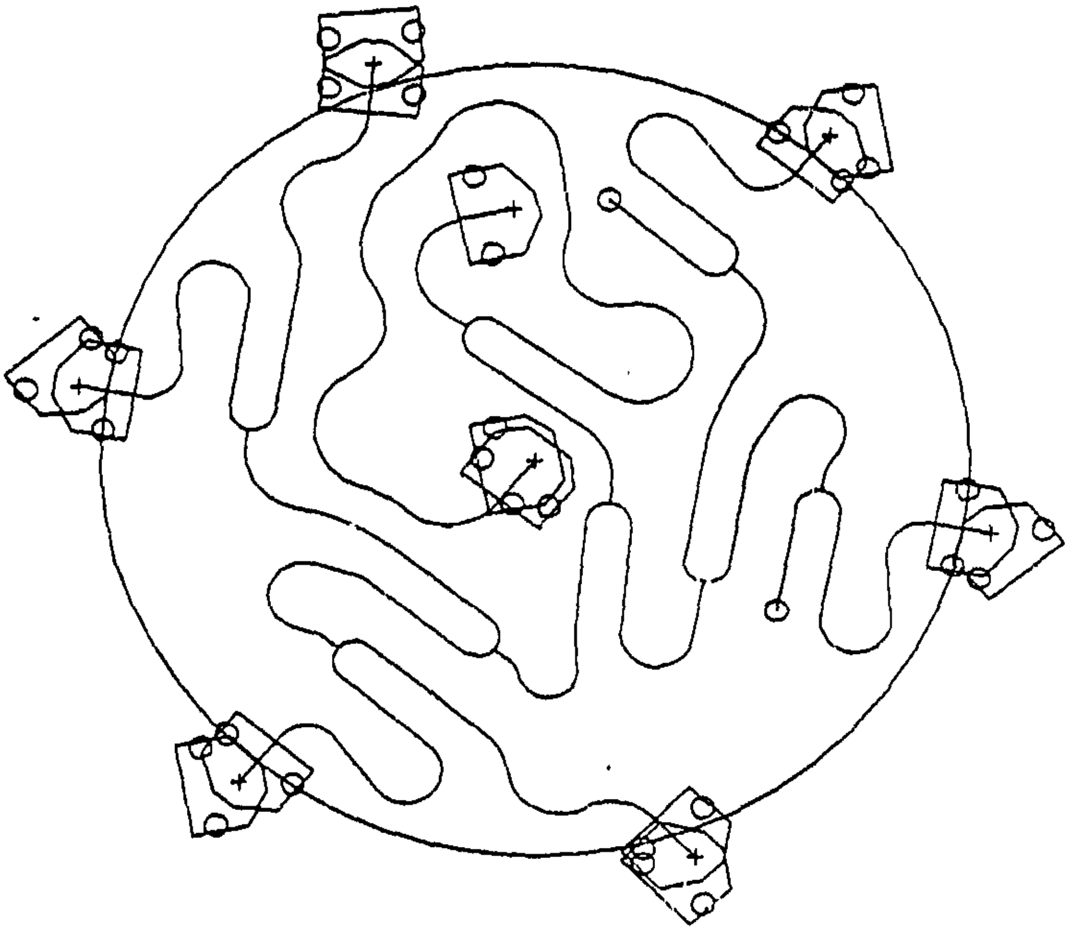


Figure 13 Divider - Combiner Dam Layout

JPL MBFN
COAXIAL CONNECTION AND OVER-ALL HEIGHT

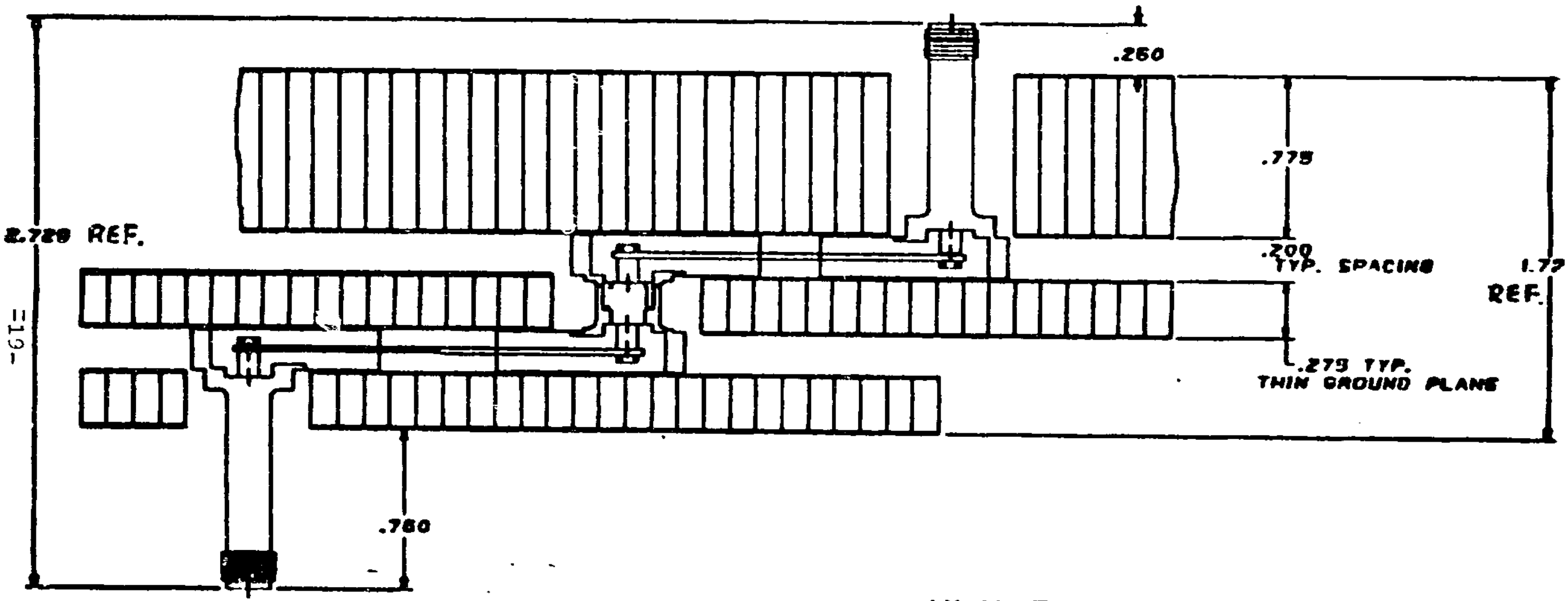


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Figure 14 Network Cross Section Showing Divider and Combiner Layers In-Out Connectors & Group Planes

TABLE A

OUTPUT PORT LOCATION

	X	Y
P1	-7.285	27.025
P2	2.405	27.025
P3	-12.145	18.624
P4	-2.445	18.624
P5	7.255	18.624
P6	-16.995	10.224
P7	-7.285	10.224
P8	2.405	10.224
P8	12.105	10.224
P10	-21.845	1.823
P11	-12.145	1.823
P12	-2.445	1.823
P13	7.255	1.823
P14	16.955	1.823
P15	-16.995	-6.577
P16	-7.285	-6.577
P17	2.405	-6.577
P18	12.105	-6.577
P19	-12.145	-14.978
P20	-2.445	-14.978
P21	7.255	-14.978

TABLE B

INPUT PORT LOCATION

	X	Y
N4	-3.045	16.826
N7	-7.895	8.226
N8	1.805	8.226
N11	-12.745	-.175
N12	-3.045	-.175
N13	6.855	-.175
N16	-7.895	-8.575
N17	1.805	-8.575

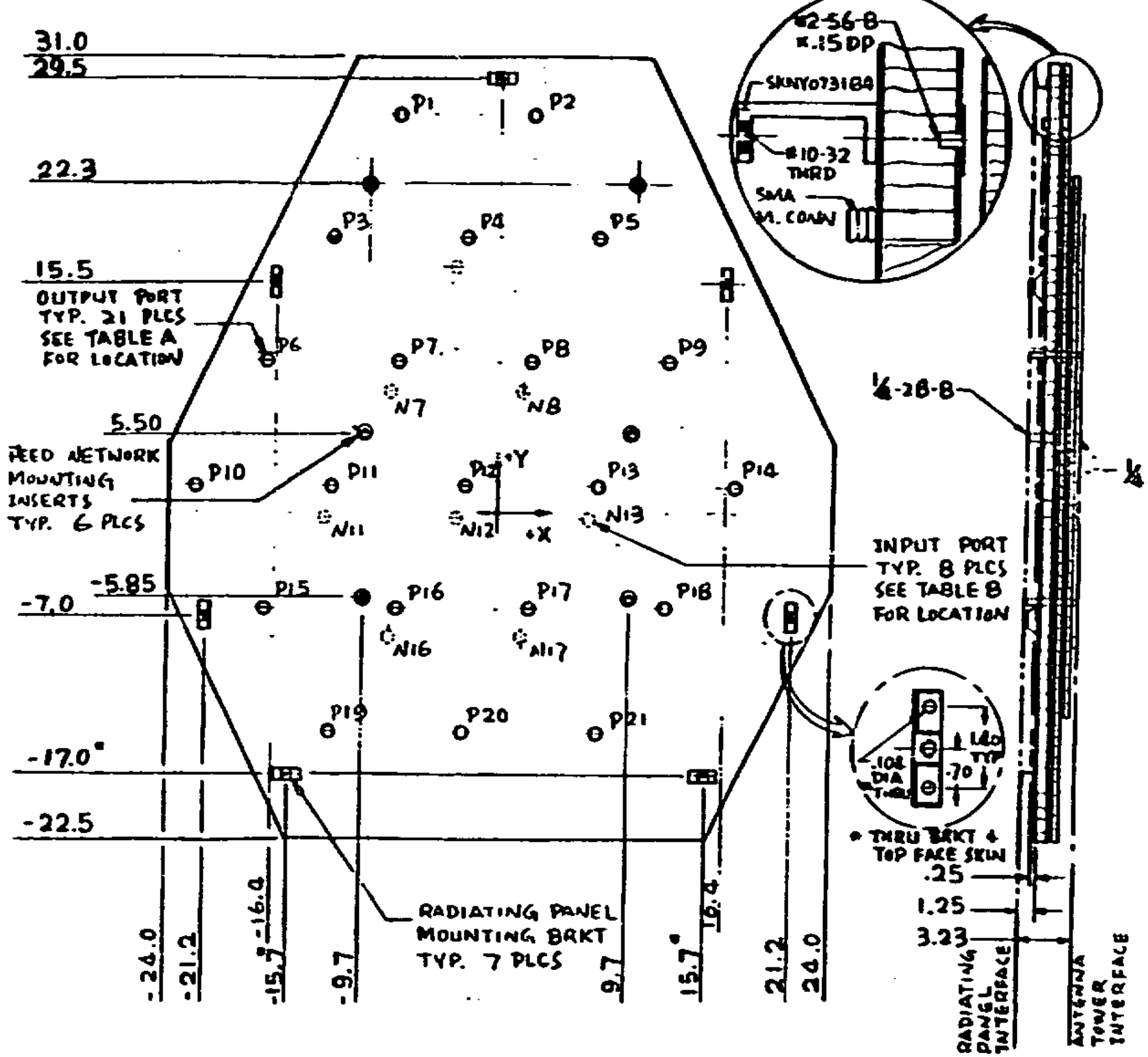

FIGURE 15 JPL BEAM FORMING NETWORK ICD

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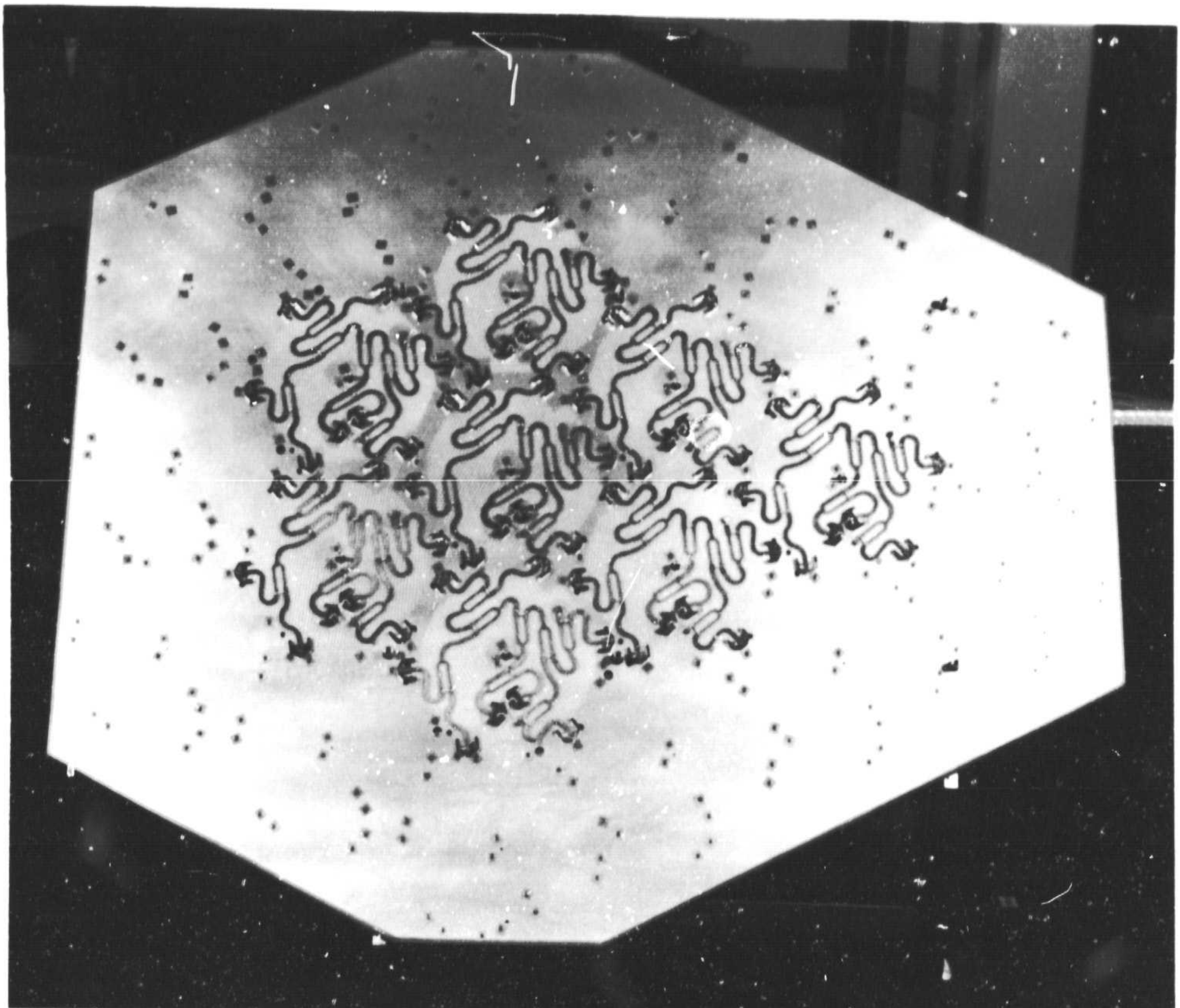

FIGURE 16 EIGHT DIVIDER NETWORKS INSTALLED ON THE GROUND PLANE

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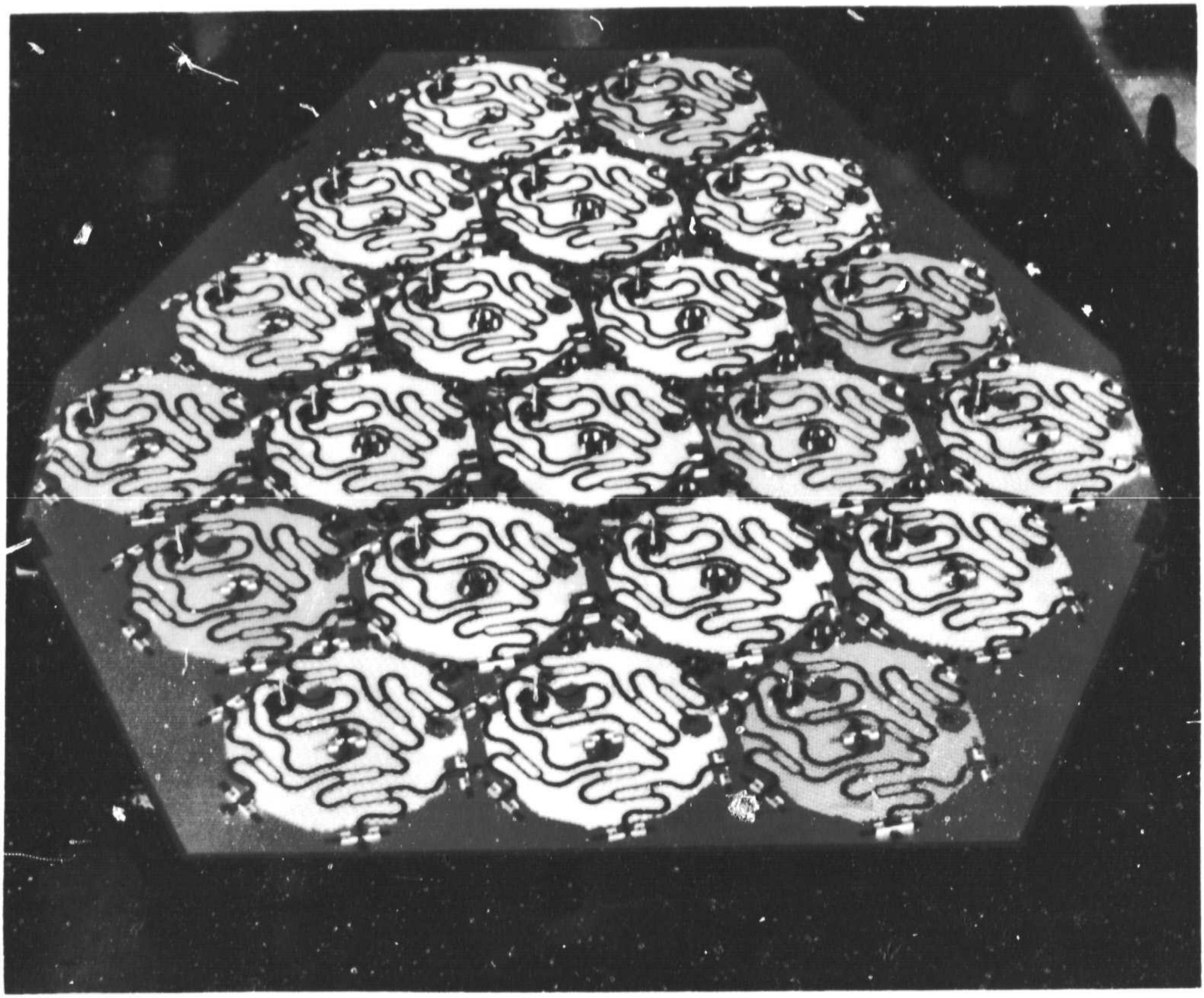

FIGURE 17 TWENTY-ONE COMBINER NETWORKS INSTALLED ON THE GROUND PLANE

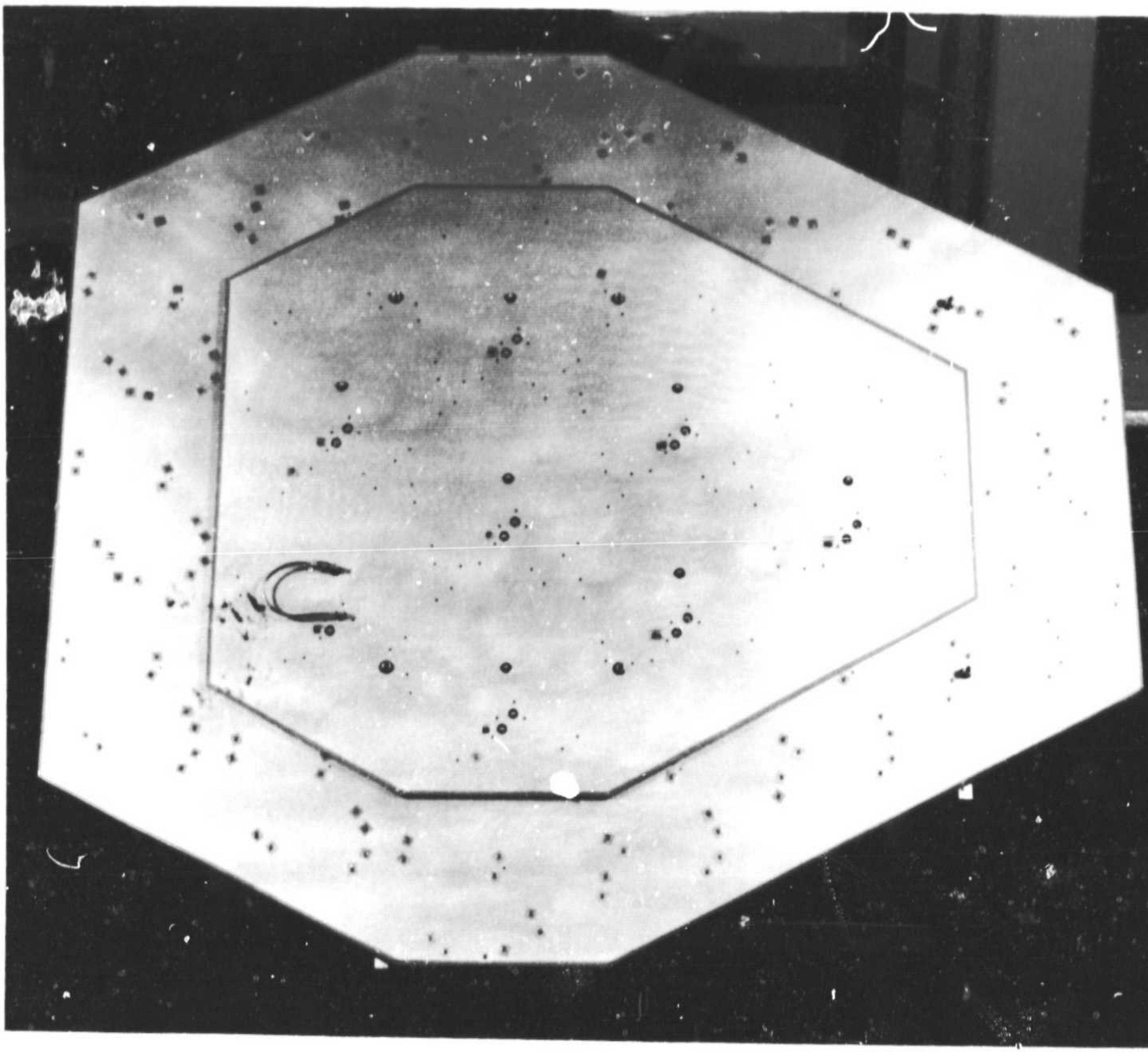

FIGURE 18 VIEW OF THE NETWORK FROM THE BEAM INPUT SIDE
WITH ONE OF EIGHT EXTERNAL CABLES INSTALLED

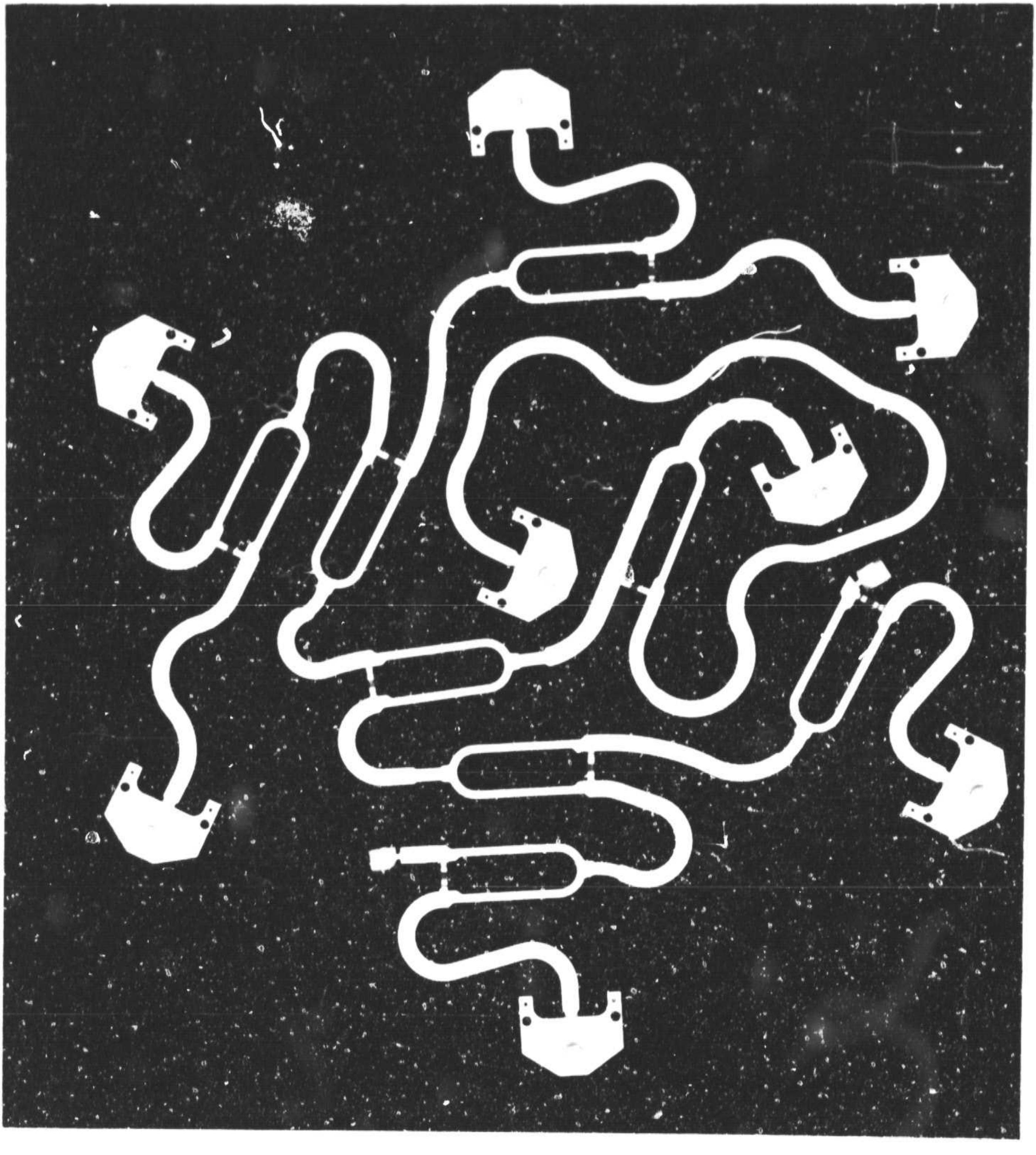

FIGURE 19 COMBINER NETWORK WITH DAMS AND RESISTORS INSTALLED

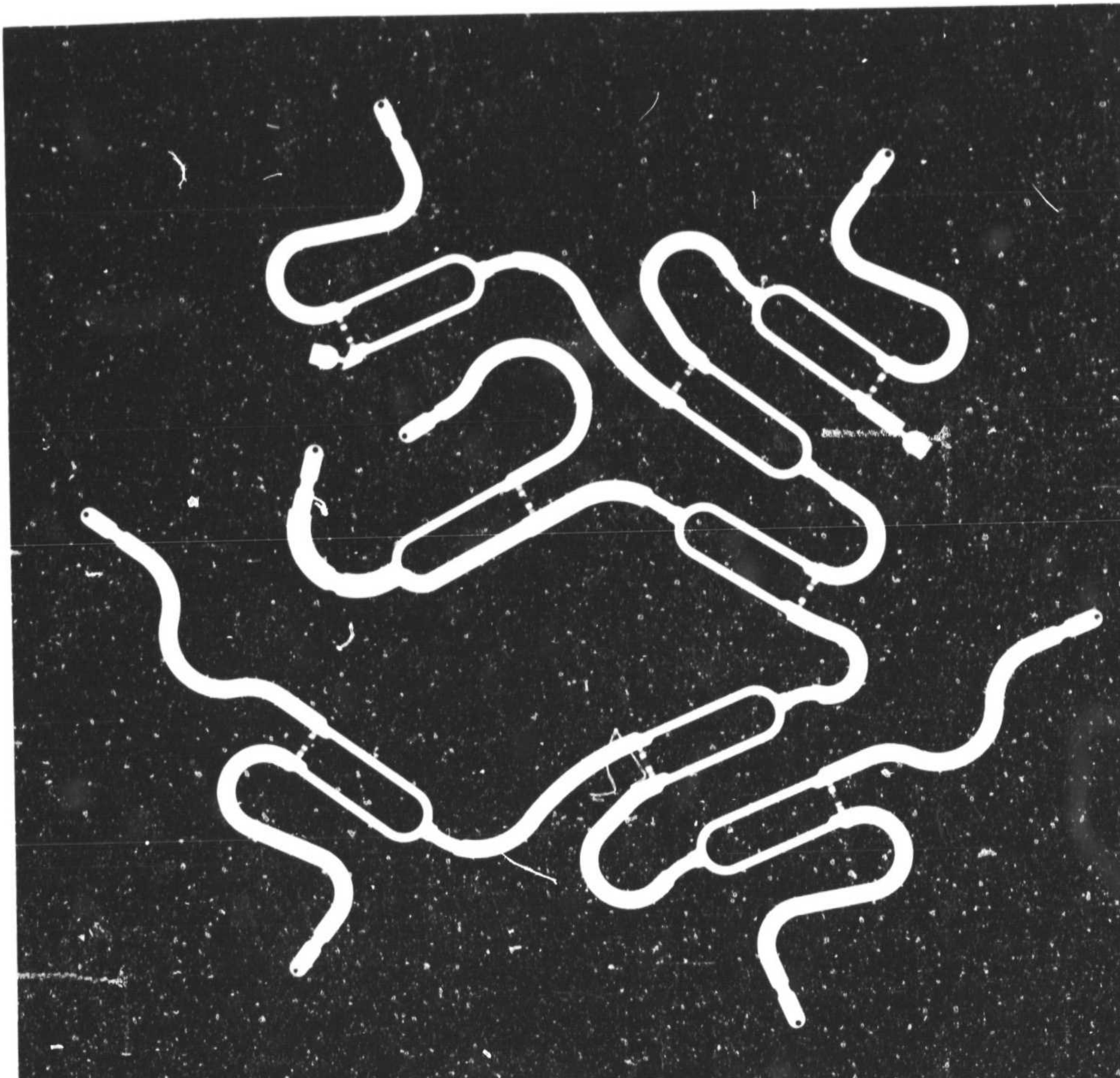

FIGURE 20 DIVIDER NETWORK WITH RESISTORS INSTALLED

ELECTRICAL PERFORMANCE

The electrical performance measurements at the center frequency 2240 MHz are summarized in Table I which displays measured VSWR's and transmission phase and attenuation. The maximum beam port VSWR is 1.08 and the maximum antenna port VSWR is 1.22.

Typical variations of parameters with frequency are displayed in Table II where it may be seen that these are quite small and should have a negligible effect.

It should be mentioned that the center element excitation can be reduced in steps of 1, 2, 3, or 5 dB by use of the external attenuators. Measured data for these attenuators are given in Table III. The set line length is selected to represent the average electrical length of the attenuators, thereby minimizing the measured phase variation with frequency. These attenuators have phaseshifts that are approximately equal in value to the phase shifts of installed zero attenuators.

Measured isolation values are very high; being greater than the specified 40 dB for all ports. Sample data is shown in Table IV and V.

When the network was first assembled the phase shifts to the edge ports, 9 to 21 were in error by up to 10 degrees. Although these errors could have been corrected by internal modifications it was decided, in consultation with JPL engineers, that there would be less risk and lower cost by using 21 short custom external connecting cables. These cables also provided a desired right angle transformation. The data of Tables I and II were measured with these custom cables installed. The barline network is quite efficient with an excess insertion loss of only 0.72 dB as shown by the calculation below. (There is the additional loss of 1.37 dB caused by the use of eight way dividers as discussed on page 6).

For a perfect network with lossless transmission lines the attenuations are as follows:

Center element attenuation
2 x 3.84 dB = 7.68 dB
Ratio = 0.1706
Edge element attenuation
2 x (2.31 + 3 x 3.01) = 22.68 dB
Ratio = 0.0054

The total power output for a perfect network with one watt input is therefore:

$$P_{out} = 0.1706 + 6 \times 0.0054 \text{ watts}$$
$$P_{out} = 0.2030 \text{ watts}$$
Insertion loss = 6.925 dB

The measured average attenuations are:

Center element attenuation
8.5 dB   Ratio = 0.1413
Edge element attenuation
22.9 dB   Ratio = 0.0051

The total power output for one watt input to the actual network is:

$$P_{out} = 0.1413 + 6 \times 0.0051 \text{ watts}$$
$$P_{out} = 0.1721 \text{ watts}$$
Insertion loss = 7.64 dB

Therefore the excess loss is:

Excess loss = 7.64 - 6.93 = 0.721 dB

TABLE I JPL NETWORK MEASUREMENTS AT 2240 GHz 09-28-84

The summary values Low, High, Average and Standard deviation refer to the edge elements, i.e. center element is not included.

CLUSTER BEAM PORT	ANTENNA PORT	TRANSMISSION PHASE degrees		TRANSMISSION ATTENUATION dB		ANTENNA VSWR
1	1	54.0		8.6		1.07
VSWR-1.07	13	56.0		22.9		1.14
	12	55.3		22.8	Low	1.12
	3	52.6	Low	23.0	High	1.06
	4	57.9	High	23.0		1.04
	2	54.2		22.9		1.09
	14	57.3		22.9		1.08
(Low+High)/2		55.6		22.9		
Average		56.3		22.9		
Standard Deviation		1.2		0.08		
2	2	60.8		8.5		
VSWR-1.07	14	61.1		22.7		
	1	61.9		22.6	Low	
	4	61.1		23		
	5	61.6		22.7		1.03
	16	58.3	Low	23.1		1.07
	15	62.4	High	23.3	High	1.2
(Low+High)/2		60.4		23.0		
Average		61.1		22.9		
Standard Deviation		1.4		0.28		
3	3	59.9		8.5		
VSWR-1.02	12	57.4		22.9		
	11	59.0		22.8		1.15
	10	62.7	High	22.9		1.14
	6	57.1	Low	23	High	1.08
	4	61.9		22.7	Low	
	1	61.5		22.9		
(Low+High)/2		59.5		22.9		
Average		59.9		22.9		
Standard Deviation		2.4		0.1		
4	4	57.7		8.4		
VSWR-1.06	1	58.4		22.9		
	3	53.5	Low	22.9		
	6	56.2		23.0	High	
	7	54.7		23.0		1.07
	5	61.2	High	22.5	Low	
	2	57.4		22.9		
(Low+High)/2		57.4		22.8		
Average		56.9		22.9		
Standard Deviation		2.75		0.19		

TABLE I JPL NETWORK MEASUREMENTS (CONTINUED)

CLUSTER BEAM PORT	ANTENNA PORT	TRANSMISSION PHASE degrees		TRANSMISSION ATTENUATION dB		ANTENNA VSWR
5	5	58.4		8.4		
VSWR-1.08	2	56.5		22.9		
	4	56.9		22.8	Low	
	7	55.0	Low	23.0	High	
	18	55.0		23.0		1.06
	17	56.6		22.8		1.13
	16	58.0	High	22.9		
(Low+High)/2		57.0		23.0		
Average		56.3		22.9		
Standard		1.16		0.23		
6	6	60.4		8.6		
VSWR-1.06	3	57.1		22.9		
	10	58.4		22.7		
	9	60.8		22.7	Low	1.19
	8	54.4	Low	23.3	High	1.06
	7	56.8		22.8		
	4	62.5	High	22.6		
(Low+High)/2		58.4		23.0		
Average		58.3				
Standard Deviation		2.9				
7	7	60.8		8.4		
VSWR-1.07	4	61.9	High	22.9		
	6	57.0	Low	22.8	Low	
	8	60.7		23.0		
	19	58.8		23.1		1.10
	18	59.0		22.8		
	5	58.3		23.4	High	
(Low+High)/2		59.5		23.1		
Average		59.3		23.0		
Standard Deviation		1.8		0.23		
8	8	58.0		8.6		
VSWR-1.04	6	56.9		22.8	Low	
	9	54.7	Low	22.8		
	21	58.5	High	22.9	High	1.15
	20	57.9		22.8		1.14
	19	56.3		22.8		
	7	58.5		22.9		
(Low+High)/2		56.6		22.9		
Average		57.1		22.8		
Standard Deviation		1.5		0.05		

TABLE II JPL ANTENNA NETWORK FEED ARRAY NETWORK TEST #3

PORT 6 TO PORT -8

FREQ-MHZ	VSWR MEAS 1	LOSS-DB MEAS 1	PHASE MEAS 1	D-PHASE MEAS 1
2225.000	1.08	23.45	51.83	-.45
2230.000	1.07	23.40	53.10	.16
2235.000	1.06	23.36	54.01	.37
2240.000	1.06	23.29	54.39	.09
2245.000	1.06	23.29	55.06	.09
2250.000	1.06	23.30	55.64	-.01
2255.000	1.07	23.36	56.08	-.25

REF PLANE EXT(CM): INPUT = .00 TRAN = 123.00
LINEARIZED FROM 2225.00 TO 2255.00
SLOPE(S) (EQUIV CM) = -11.20

PORT -14 TO PORT 1

FREQ-MHz	VSWR MEAS 1	LOSS-DB MEAS 1	PHASE MEAS 1	D-PHASE MEAS 1
2225.000	1.09	22.95	54.91	-.08
2230.000	1.09	22.91	55.76	-.01
2235.000	1.09	22.88	56.63	.07
2240.000	1.08	22.88	57.32	-.02
2245.000	1.08	22.84	58.25	.11
2250.000	1.07	22.81	59.56	-.13

REF PLANE EXT (CM): INPUT = .00 TRAN = 123.00
LINEARIZED FROM 2225.00 TO 2255.00
SLOPES(S) (EQUIV CM) = -13.11

PORT -2 TO PORT 1

FREQ-MHz	VSWR MEAS 1	LOSS-DB MEAS 1	PHASE MEAS 1	D-PHASE MEAS 1
2225.000	1.09	22.86	51.93	.03
2230.000	1.09	22.85	52.70	.00
2235.000	1.09	22.87	53.42	-.05
2240.000	1.09	22.86	54.16	-.10
2245.000	1.09	22.87	55.12	.09
2250.000	1.09	22.87	55.95	.14
2255.000	1.09	22.91	56.49	-.11

REF PLANE EXT(CM): INPUT = .00 TRAN = 123.00
LINEARIZED FROM 2225.00 TO 2255.00
SLOPES(S) (EQUIV CM) = -12.96

TABLE II JPL ANTENNA NETWORK FEED ARRAY NETWORK TEST #3 (Continued)
PORT -1 TO PORT 1

FREQ-MHz	VSWR MEAS 1	LOSS-DB MEAS 1	PHASE MEAS 1	D-PHASE MEAS 1
2225.000	1.09	8.54	53.87	-.01
2230.000	1.09	8.55	53.90	-.03
2235.000	1.08	8.56	53.97	-.01
2240.000	1.07	8.56	54.03	.01
2245.000	1.07	8.57	54.19	.11
2250.000	1.06	8.57	54.17	.04
2255.000	1.06	8.60	54.07	-.10

REF PLANE EXT(CM): INPUT = .00 TRAN = 123.00
LINEARIZED FROM 2225.00 TO 2255.00
SLOPES(S) (EQUIV CM) = -.82

TABLE III FIXED ATTENUATOR MEASUREMENTS
(at 2.240 GHz for a set line length of 1.90 cm)

0 dB NOMINAL

NUMBER	LOSS dB	PHASE (degrees)	VSWR
00	0.00	0.06	1.03
01	0.00	-0.63	1.03
02	-0.01	-0.81	1.02
03	-0.01	-0.61	1.03
04	-0.01	-0.42	1.02
05	-0.00	-0.53	1.03
06	0.00	-0.66	1.02
07	-0.01	-0.84	1.03
08	-0.01	-0.92	1.01
09	0.00	-0.78	1.03

1 dB NOMINAL

NUMBER	LOSS dB	PHASE (degrees)	VSWR
10	1.05	-1.64	1.04
11	1.05	-0.83	1.05
12	1.02	-0.53	1.05
13	0.93	-1.39	1.03
14	0.96	-0.72	1.04
15	1.03	-1.35	1.04
16	1.01	-1.29	1.03
17	0.92	-0.78	1.03
18	0.98	-1.47	1.04
19	1.00	-0.55	1.02

2 dB NOMINAL

NUMBER	LOSS dB	PHASE (degrees)	VSWR
20	2.07	-0.28	1.05
21	2.07	-0.80	1.06
22	2.02	0.05	1.05
23	2.06	-0.11	1.06
24	2.05	-0.43	1.06
25	1.91	-2.76	1.09
26	1.87	-2.74	1.11
27	2.01	-2.27	1.08
28	2.05	-3.03	1.09
29	2.06	-3.16	1.09

3 dB NOMINAL

NUMBER	LOSS dB	PHASE (degrees)	VSWR
30	3.07	-0.52	1.04
31	3.05	-0.02	1.04
32	3.06	0.10	1.04
33	3.03	-0.28	1.03
34	3.02	-0.59	1.05
35	3.05	-0.12	1.04
36	2.99	-0.14	1.03
37	3.05	-0.24	1.04
38	3.06	-0.08	1.03
39	3.05	0.02	1.04

5 dB NOMINAL

NUMBER	LOSS dB	PHASE (degrees)	VSWR
50	4.94	1.01	1.03
51	4.96	0.67	1.03
52	4.86	1.00	1.03
53	4.95	0.49	1.03
54	4.97	0.42	1.02
55	4.87	0.00	1.02
56	4.87	0.86	1.02
57	4.94	0.77	1.02
58	4.92	0.35	1.02
59	4.91	0.86	1.02

TABLE IV ISOLATION MEASUREMENTS FOR BEAM PORTS AT 2240 MHz
VALUES in dB

Beam Ports	1	2	3	4	5	6	7	8
1		48	52	56	79	60	72	80
2			65	40	48	71	41	80
3				44	69	49	78	65
4					46	52	45	57
5						70	52	60
6							46	53
7								46

TABLE V ISOLATION MEASUREMENTS FOR ANTENNA PORTS AT 2240 MHz
VALUES IN dB*

Antenna Port	Antenna Ports		Beam Ports	
	7	4	1	4
1	---	60	---	---
2	---	54	---	---
3	---	62	---	---
4	56	---	---	---
5	62	65	88	---
6	59	68	79	---
7	---	56	93	---
8	57	---	86	81
9	---	69	83	89
10	58	---	80	90
11	---	67	85	91
12	91	---	---	84
13	---	68	---	85
14	91	---	---	80
15	---	69	59	75
16	67	---	80	76
17	69	63	91	82
18	63	---	95	76
19	57	66	91	89
20	---	---	86	88
21	66	---	90	82

*Locations of numbered ports are shown in Figure 1